NASA TECHNICAL MEMORANDUM

NASA TM X-3093

NASA TM X-3093

PERFORMANCE OF A SHORT ANNULAR DUMP DIFFUSER USING WALL TRAILING-EDGE SUCTION

by Albert J. Juhasz

Lewis Research Center

Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • AUGUST 1974

1. Report No. NASA TM X-3093	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PERFORMANCE OF A SHORT ANNULAR DUMP DIFFUSER USING WALL TRAILING-EDGE SUCTION		5. Report Date August 1974
		6. Performing Organization Code
7. Author(s) Albert J. Juhasz		8. Performing Organization Report No. E-7944
		10. Work Unit No. 501-24
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A short annular dump (abrupt flow area change) diffuser was tested with suction through wall trailing-edge slots at inlet Mach numbers of 0.19 and 0.27 and at near ambient inlet temperature and pressure, with suction flow varied from zero to 10 percent of the inlet air mass-flow rate. The overall ratio of diffuser exit area to inlet area was 4.0, and the ratio of length to inlet height was 2.0. By applying suction flow separately on either wall or to both walls simultaneously, the original annular jet profile could be altered to either a hub- or tip-biased profile. Diffuser effectiveness was increased from about 25 percent with no suction to 50 percent at 6 percent outer-wall suction and to 52 percent at a combined suction rate on both walls of 10.25 percent. At the same time, diffuser total pressure loss was reduced by one-fourth.

17. Key Words (Suggested by Author(s)) Combustor flow control Diffuser bleed	18. Distribution Statement Unclassified - unlimited Category 01

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	21	$3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

PERFORMANCE OF A SHORT ANNULAR DUMP DIFFUSER USING WALL TRAILING-EDGE SUCTION

by Albert J. Juhasz

Lewis Research Center

SUMMARY

A short annular dump diffuser having an abrupt flow area change of 4 was tested with suction through trailing-edge slots continuous over the full circumference on both the inner and outer walls, at inlet Mach numbers of 0.19 and 0.27. Inlet pressures and temperatures were at near ambient conditions, and the suction rate was varied from zero to about 10 percent of the inlet air mass-flow rate. The included divergence angle of the diffuser approach section was 7° over an approach length of 1.25 times annular inlet height, resulting in an approach section area ratio of 1.15. The overall ratio of diffuser exit area to inlet area was 4.0; and the ratio of length to inlet height, as defined by the location of exit instrumentation, was 2.0.

Although it was not possible to obtain attached flow simultaneously on both walls of the diffuser exit passage, the original annular-jet-type exit velocity profile could be changed to either a hub-biased or a tip-biased profile by applying suction flow separately on either wall or to both walls simultaneously. Applying suction flow to both walls in some cases also resulted in erratic and abrupt changes from a hub-biased to a tip-biased profile, or conversely, depending on the relative values of the inner- and outer-wall suction flow rates.

Some performance improvement was also obtained with suction, as indicated by a rise in diffuser effectiveness from 25 percent with no suction to 50 percent at 6 percent outer-wall suction and to 52.6 percent at a combined suction rate of 10.25 percent on both walls. At the same time, diffuser total pressure loss was reduced by approximately one-fourth. Diffuser performance was found to be better with tip-biased than with hub-biased exit velocity profiles.

INTRODUCTION

An investigation was conducted to determine the effect of wall suction on the exit velocity profile and performance of a short experimental annular diffuser having an abrupt flow area change between its inlet and exit passages. The advantages of short diffuser-combustor systems in gas turbine applications, such as reduced engine length and weight, are discussed in reference 1. However, short diffusers usually incur performance losses caused by flow separation. Reference 2 proposed and reported on the use of diffuser bleed (suction) to control the exit velocity profile and to reduce the performance losses of a short annular diffuser with circular-arc wall contours.

A more simple type of short diffuser configuration from a manufacturing point of view is the dump diffuser, which has an abrupt area change between its inlet and exit flow passages. This type of diffuser has been used in full-scale combustor tests at the Lewis Research Center, as discussed in reference 3. However, no suction was used in these tests; neither were any performance data obtained for the diffuser alone during these combustor-oriented experiments. In an effort to reproduce in the laboratory the snow cornice flows observed by Ringleb (ref. 4), a two-dimensional duct with a variable-step area change on its lower wall followed by a wall suction slot was tested in reference 5. Results showed that smooth expansion of the flow downstream of the step area change could be obtained if sufficient suction per unit wall span was applied. In reference 6 similar conclusions were reached from an investigation on the effect of suction on flow in a pipe with a sudden enlargement. The required suction flow was found to vary with the suction slot design. For the design yielding maximum pressure recovery the required suction flow was about 7 percent on a volumetric basis.

In the present investigation the work of reference 6 was extended from a tubular geometry to an annular geometry. Inner- and outer-wall suction was applied at the downstream edges of these walls through circumferentially continuous slots. The design of these suction slots was arrived at by extrapolation of the results of reference 6. The diffuser approach section had an included divergence angle of 7°, resulting in an area ratio of 1.15. The overall ratio of diffuser exit area to inlet area was 4.0; and the ratio of length to inlet height, as determined by the location of the diffuser exit instrumentation was 2.0. The diffuser inlet passage flow area was 304 square centimeters (47.12 in.^{2}).

Velocity profiles, diffuser effectiveness, and diffuser total pressure loss data were obtained for nominal inlet Mach numbers of 0.19 and 0.27 at suction rates of zero to 10 percent, by weight, of total inlet flow. All testing was conducted with air at ambient temperature and pressure.

SYMBOLS

A	area
AR	diffuser area ratio
B	bleed-flow fraction of total mass-flow rate
g_c	dimensional constant
H	diffuser inlet passage height
L	diffuser approach length
M	average Mach number at an axial station
$\dot{m}$	mass-flow rate
P	average pressure at an axial station
p	local pressure at a radial position
R	gas constant for air
T	temperature
V	average velocity at an axial station
v	local velocity at a radial position
X	downstream distance to exit station
γ	specific-heat ratio
ϵ	diffuser efficiency, eq. (5)
η	diffuser effectiveness, eq. (3)

Subscripts:

m	maximum
r	local value at a given radial position
0	stagnation condition
1	diffuser inlet station
2	diffuser exit station

APPARATUS AND INSTRUMENTATION

Flow System

The investigation was conducted in the test facility described in reference 2. A schematic of the facility flow system is shown in figure 1. Air, at a pressure of approximately 100 N/cm^2 abs (145 psia) and ambient temperature, is supplied to the facility by a remotely located compressor station. This air feeds the three branches of the flow system.

The center branch (identified as "main air line") provides the airflow through the test diffuser. The air flowing through this branch is metered by a square-edged orifice installed with flange taps according to ASME standards. The air is then throttled to near atmospheric pressure by a flow control valve before entering a mixing chamber from which it flows through the test diffuser. The air discharging from the diffuser is exhausted to the atmosphere through a noise-absorbing duct.

The two other branches of the flow system supply the two air ejectors, which produce the required vacuum for the inner- and outer-wall diffuser bleed flows. The ejectors are designed for a supply air pressure 68 N/cm^2 abs (100 psia) and are capable of producing absolute pressures as low as 2.38 N/cm^2 (7.0 in. Hg).

The diffuser inner- and outer-wall bleed flows are also metered by square-edged orifices. These orifices are also installed with flange taps according to ASME specifications in the suction flow lines that connect diffuser inner- and outer-wall bleed chambers to their respective ejector vacuum sources.

Diffuser Test Apparatus

The diffuser test apparatus used in this investigation was essentially that used in reference 2 but for a few modifications. An axial section of the apparatus is shown in figure 2. As in reference 2 the centerbody that formed the inner annular surface was cantilevered from eight equally spaced support struts located 30 centimeters (12 in.) upstream of the diffuser inlet passage. This construction minimized the possibility of strut flow separation having an undesirable effect on the circumferential profile of inlet velocity.

Diffuser Walls

The removable walls forming the diffuser approach section were positioned in the diffuser test apparatus as shown in figure 2. The wall geometry and suction slot configuration details are shown in figure 3. To prevent flow separation upstream of the suction slots, the annular diffuser approach section was designed to be symmetrical with a total included angle of 7^{o}, resulting in a diffuser approach area ratio of 1.15 at a length-to-inlet-height ratio L/H of 1.25. The overall diffuser area ratio was 4.0; and the overall diffuser length, as defined by the position of the exit instrumentation, was twice the inlet passage height. The suction slot geometry was designed for maximum pressure recovery at suction rates of 2 to 5 percent on each wall by extrapolating the results of reference 6.

The inner and outer suction chambers were formed by the inner spaces of the toroidal wall design. These toroidal walls were held in place by 12 equally spaced pipe nipples of 1.50-centimeter (0.622-in.) internal diameter. These short pipes also served to duct the inner- and outer-wall bleed flows to the inner-wall suction plenum and the outer-wall suction manifold, respectively.

Units

The U.S. customary system of units was used for primary measurements and calculations. Conversion to SI units (Système International d'Unités) was done for reporting purposes only. In making the conversion, consideration was given to implied accuracy, which may result in rounding off the values expressed in SI units.

Diffuser Instrumentation

The essential diffuser instrumentation is indicated in figures 2 and 3. Diffuser inlet total pressure was obtained from three fivepoint total pressure rakes located at station 1 and equally spaced around the annular circumference. Inlet static pressure was measured by three wall taps also located at station 1.

Diffuser exit total and static pressures were obtained from three nine-point pitot static rakes that could be rotated in a circumferential direction and translated axially. For this investigation these rakes were positioned downstream of the diffuser inlet plane at a distance equal to twice the inlet passage height. All rake pressures were measured by three Scanivalves, each ducting pressures from a maximum of 48 ports to a flush-mounted, ±0.69-N/cm^2 (±1.0-psid), strain-gage transducer. The valve dwell time at

each port was 0.2 second, or over three times the interval required to reach steady state. Continuous calibration of the Scanivalve system was provided by ducting known pressures to several ports. Visual display of pressure profiles was made available by also connecting all inlet rakes and two exit rakes to common well manometers using dibutyl phthalate fluid (specific gravity, 1.04). In addition, flow behavior in the diffuser exit passage could also be monitored with tufts.

All other pressure data, such as orifice line pressures for the main air line and the subatmospheric bleed-air lines, were obtained from individual strain-gage pressure transducers. The temperatures of the various flows were measured with copper-constantan thermocouples.

All data were remotely recorded on magnetic tape for subsequent processing with a digital data reduction program. In addition, any test parameter could be displayed in the facility control room by means of a digital voltmeter.

PROCEDURE

Performance Calculations

The digital data reduction program mentioned previously was used to evaluate the overall diffuser performance in terms of radial profile of exit velocity, diffuser effectiveness, total pressure loss, and diffuser efficiency. The values of the latter three figures of merit were expressed as percentages.

Intermediate computations included average static and total pressures, local and average Mach numbers, and ratios of local to average Mach number; that is, the equivalent of the ratios of local to average velocity. The average pressures and Mach numbers at the diffuser exit (P_2, P_{02}, and M_2) were computed by trapezoidal integration using area-ratio-weighted pressures at the various radial positions. At the diffuser inlet, straight arithmetic averages were computed. Local Mach numbers for each pitot tube were computed from the compressible flow relation

$$M_r = \sqrt{\frac{2}{\gamma - 1}\left[\left(\frac{p_0}{p}\right)^{(\gamma-1)/\gamma} - 1\right]} \qquad (1)$$

where p_0 and p represent the measured local total and static pressures and γ represents the specific-heat ratio, set equal to 1.4 for the near ambient conditions of this investigation.

Diffuser and bleed airflow rates were computed from the respective orifice pressures and temperatures. As a check on the arithmetically averaged inlet Mach number, a mean effective inlet Mach number was also computed by iteration from inlet airflow

rate, total pressure, temperature, and area data as shown hereinafter.

$$M_1 = \frac{\dot{m}_1}{P_{01}A_1}\sqrt{\frac{RT_{01}}{\gamma g_c}}\left(1 + \frac{\gamma - 1}{2} M_1^2\right)^{(\gamma+1)/2(\gamma-1)} \tag{2}$$

The velocity ratios at each radial position needed to generate velocity profiles were obtained from the circumferential averages of the ratios of local to average Mach number. A plotting routine was used to generate the velocity profiles by computer with output on microfilm.

Diffuser effectiveness was computed from the following relation:

$$\eta = \frac{P_2 - P_1}{(P_{01} - P_1)\left[1 - \left(\frac{1 - B}{AR}\right)^2\right]} \times 100 \tag{3}$$

Equation (3) is an approximation expressing the ratio of actual to ideal conversion of inlet dynamic pressure to exit static pressure for the case of compressible flows through a diffuser with wall bleed for $M_1 \leq 0.5$ and $AR \geq 2$. For the conditions of the present study the use of equation (3) introduced an approximation error of less than 0.5 percent. A derivation of equation (3) and its limitations is shown in reference 7.

The total pressure loss was defined as

$$\frac{\Delta P_0}{P_0} = \frac{P_{01} - P_{02}}{P_{01}} \times 100 \tag{4}$$

Diffuser efficiency was computed fro… …e relation

$$\epsilon = \frac{\left(1 + \frac{\gamma - 1}{2} M_1^2\right)\left(\frac{P_{02}}{P_{01}}\right)^{(\gamma-1)/\gamma} - 1}{\frac{\gamma - 1}{2} M_1^2} \times 100 \tag{5}$$

The values of the respective parameters computed by equations (3) to (5) are expressed as percentages. Equation (5) was derived in reference 8 for the case where the diffuser exit velocity is negligible. This restriction can be removed from equation (5), as shown in reference 7, by making a minor change in the definition and subsequent derivation of the diffuser efficiency parameter. Hence equation (5), as used in this report, relates the total energy level available at the exit of a diffuser to the upstream total energy level, with the inlet static enthalpy being the reference.

Test Conditions

The following are typical diffuser inlet conditions:

Total pressure, N/cm^2 abs (psia)	9.9 to 10.3 (14.3 to 14.9)
Static pressure, N/cm^2 abs (psia)	9.6 to 9.7 (13.9 to 14.0)
Temperature, K (^{o}F)	295 to 296 (71 to 74)
Mach number	0.19 to 0.274
Velocity, m/sec (ft/sec)	65 to 95 (215 to 310)
Reynolds number (based on inlet passage height)	2.3×10^5 to 3.35×10^5
Bleed rate, percent of total flow	0 to 10.1

RESULTS AND DISCUSSION

The performance of a short, abrupt-area-change, annular diffuser equipped with suction capability was evaluated in terms of radial profiles of velocity, diffuser effectiveness, and total pressure loss for two inlet Mach numbers, with total suction rates ranging from zero to 10 percent. A summary of performance data is given in table I.

Radial Profiles of Velocity

The inlet and exit radial velocity profiles measured without the use of suction for inlet Mach numbers of 0.27 and 0.19 are shown in figures 4(a) and (b), respectively. These and all other profiles presented here were obtained by plotting the ratio of local velocity at a radial position to the average velocity in a particular plane (inlet or exit) as a function of increasing radial span position. The local velocity at a radial span position was obtained by taking the arithmetic average of local velocities at three circumferential positions. Circumferential variations from these averaged profiles were about ±2 percent at the diffuser inlet and about ±30 percent at the exit plane. Comparison of figures 4(a) and (b) shows that both the inlet and exit velocity profiles were practically the same, both showing a slight hub bias, for the two inlet Mach numbers tested. The corresponding Reynolds numbers based on inlet passage height ranged from 2.3×10^5 to 3.4×10^5, indicating fully developed turbulent flow at the diffuser inlet plane. Since the shape of the inlet velocity profiles is determined by the geometry of the annular inlet passage, it is not surprising that the inlet profiles were the same as those determined in reference 7, which used the same inlet geometry. Moreover, as shown in reference 7 and also in subsequent figures, the inlet profiles were not affected by suction rate.

The exit profile shape, however, although also invariant with inlet Mach number, was strongly affected by wall suction. Figure 5 shows typical velocity profiles obtained with suction through both the inner- and the outer-wall slots. As pointed out previously, the inlet profile was not affected by suction. Symmetric exit velocity profiles were unstable with suction on both walls. These profiles tended to become hub biased as shown in figure 5(a) or tip biased (fig. 5(b)), depending on the relative values of the inner- and outer-wall suction flow rates. Figure 5(c) shows an example of an unstable profile in the process of changing from a fully attached hub flow, obtained with 3.66 percent inner-wall suction and 6.1 percent outer-wall suction, to a fully attached tip flow when the outer-wall suction flow was gradually increased to 6.5 percent. The initial and final profiles are shown dashed. Other profiles of this type were obtained for the last six readings in table I.

Stable tip-biased exit velocity profiles were obtained with outer-wall suction as shown in figure 6. With about 2.7 percent outer-wall suction (fig. 6(a)), the flow was still separated from both walls, but the profile was mildly tip biased. At a suction rate of 4.0 percent (fig. 6(b)), the flow was starting to become attached to the outer wall of the exit passage. Figure 6(c) shows complete attachment to the exit passage outer wall at a suction rate of about 6 percent, as indicated by the relatively large value of velocity ratio at 90 percent of span and confirmed by probing the flow with tufts. The required suction rate is in reasonable agreement with the results of reference 6 for flow in a pipe with a sudden enlargement.

Diffuser Effectiveness

The effect of suction on diffuser effectiveness, as defined in equation (3), is shown in figure 7 for various exit velocity profiles and for the two inlet Mach numbers of this test program. It is interesting, though not surprising, that the data fall on three distinct curves. The lowest diffuser effectiveness values were obtained with hub-biased profiles. This is to be expected since, for these profiles, separated flow existed in the outer portion of the annular exit passage. The large fraction of total flow area associated with this separated portion of the exit passage tended to limit increases in diffuser effectiveness with suction, as shown by the curve for hub-biased profiles. Nevertheless, a modest improvement in performance was obtained by the use of edge suction, even for hub-biased profiles. Diffuser effectiveness increased from about 23 percent without suction to about 45 percent with 9 percent total suction. The diffuser effectiveness value obtained without suction was sufficiently high to indicate that no flow separation had occurred upstream of the suction slots.

The performance penalty due to exit passage flow separation was considerably

smaller for tip-biased profiles. These profiles show that flow separation was confined to the near hub region, which represents a smaller fraction of the exit flow area. However, with suction on both walls a higher total suction rate was required to cause flow attachment to the outer wall of the exit passage than with outer-wall suction only. This is indicated by the top two curves, which show that, with outer-wall suction only, about 6 percent suction (facility limit) was required to obtain a diffuser effectiveness of 50 percent. With suction on both walls (suction rates on each wall are given in table I), a suction rate between 9 and 10 percent was required for a diffuser effectiveness of 50 percent. An obvious reason is that with hub flow separation the inner-wall trailing-edge suction slot, instead of removing the upstream boundary layer, merely draws in part of the separated downstream flow. Thus, the inner-wall suction slot does not contribute to any improvement in diffuser effectiveness when the flow is separated from the inner wall of the exit passage.

Diffuser Total Pressure Loss

The decrease of diffuser total pressure loss with suction rate is shown in figure 8 for the two test Mach numbers. The data trends are in good agreement with the explanation of flow behavior based on diffuser effectiveness data. For both inlet Mach numbers the greatest reduction in total pressure loss was obtained by using outer-wall suction only. At an inlet Mach number of 0.27 this reduction was from 3.1 percent without suction to 2.35 percent at an outer-wall suction rate of 4 percent. These values represent a 25 percent reduction in total pressure loss. A similar decrease in total pressure loss was noted at the 0.19 inlet Mach number condition.

Diffuser Efficiency

Values of diffuser efficiency, as computed from equation (5), are shown in table I. Since this parameter is based on inlet and exit effective total pressures, its value is sensitive to variations in total pressure profile. The relation between diffuser efficiency, diffuser effectiveness, and total pressure loss was discussed in detail in reference 7. As in reference 7, the value of diffuser efficiency was found to exceed that of diffuser effectiveness. The two values approached each other as the exit velocity profile became less peaked.

Projected Performance in Combustors

This study was conducted to determine the effect of suction on the performance of an abrupt-area-change (dump) diffuser. In a gas turbine engine, such a diffuser can drastically reduce the separation between the compressor exit plane and the combustor inlet plane and thus bring about a reduction in engine length and weight.

It was demonstrated that the annular jet-flow exit velocity profile could be altered to either a hub-biased or a tip-biased profile by drawing a small amount of suction flow through the circumferential inner- or outer-wall edge slots. At the same time, modest gains in diffuser performance were also obtained. Although it was not possible to obtain stable flow in the exit passage with symmetric exit velocity profiles, subsequent testing with perforated-plate blockage in the diffuser exit passage indicated that a dump diffuser could give satisfactory performance when placed upstream of a gas turbine combustor. Preliminary tests show that the blockage produced in the diffuser exit passage by a combustor dome tends to stabilize the exit velocity profile regardless of profile shape. Hence, the use of inner- and outer-wall bleed would permit adjusting the airflow distribution to meet the required flow splits between the combustor primary and secondary zones at various engine operating conditions. Moreover, the penalty on engine cycle efficiency can be minimized by using the bleed flow for turbine cooling and auxiliary drive purposes.

SUMMARY OF RESULTS

Performance tests were conducted on a short dump (abrupt area change) annular diffuser equipped with suction capability through peripheral edge slots on both the inner and outer diffuser walls. The following results were obtained:

1. Without the use of suction the exit velocity profile was that of an annular jet flow.

2. The diffuser exit flow became fully attached to the inner wall of the exit passage at about 3.7 percent inner-wall suction and to the outer wall at about 6.1 percent outer-wall suction.

3. Suction on both the inner and outer walls produced either hub-biased or tip-biased profiles depending on the relative values of the inner- and outer-wall suction flow rates.

4. The inlet velocity profile was not affected by suction or inlet Mach number, and the effect of inlet Mach number on exit velocity profile was negligible.

5. Diffuser effectiveness (ratios of actual to ideal static pressure recovery) was increased from about 25 percent with no suction to about 50 percent at 6 percent outer-wall suction and to 52.6 percent with 10.25 percent combined suction on both walls.

6. Diffuser total pressure loss at an inlet Mach number of 0.27 was reduced from 3.1 percent without suction to 2.35 percent at an outer-wall suction rate of 4 percent.

7. Performance gains with hub-biased exit velocity profiles were smaller than those obtained with tip-biased exit velocity profiles.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 3, 1974,
501-24.

REFERENCES

1. Roudebush, William H.: State of the Art in Short Combustors. Paper 68-22, ICAS, Sept. 1968.
2. Juhasz, Albert J.; and Holdeman, James D.: Preliminary Investigation of Diffuser Wall Bleed to Control Combustor Inlet Airflow Distribution. NASA TN D-6435, 1971.
3. Niedzwicki, Richard W.; Juhasz, Albert J.; and Anderson, David N.: Performance of a Swirl-Can Primary Combustor to Outlet Temperatures of 3600° F (2256 K). NASA TM X-52902, 1970.
4. Ringleb, F.O.: Flow Control by Generation of Standing Vortices and the Cusp Effect. Aero. Eng. Rept. 317, Princeton University, July 1955.
5. Heskestad, Gunnar: Remarks on Snow Cornice Theory and Related Experiments with Sink Flows. Jour. Basic Eng., ASME Trans., vol. 88, no. 6, June 1966, pp. pp. 539-549.
6. Heskestad, Gunnar: Further Experiments with Suction at a Sudden Enlargement in a Pipe. Paper 69-WA/FE-27, ASME, Nov. 1969.
7. Juhasz, Albert J.: Performance of an Asymmetric Short Annular Diffuser with a Nondiverging Inner Wall Using Suction. NASA TN D-7575, 1974.
8. Shapiro, Ascher H.: The Dynamics and Thermodynamics of Compressible Fluid Flow. Vol. 1, Ronald Press Co., 1953, pp. 151-152.

TABLE I. - DIFFUSER PERFORMANCE DATA

Reading	Diffuser inlet Mach number	Airflow rate		Inlet pressure				Inlet total temperature		Inner wall	Outer wall	Total	Exit profile peak		Diffuser effectiveness, η, percent	Diffuser efficiency, ϵ, percent	Total pressure loss, $\Delta P/P$, percent
		kg/sec	lbm/sec	Total		Static				Suction rate, percent			Position, percent of annular span	Ratio, v/V			
				N/cm^2	psia	N/cm^2	psia	K	^{o}F								
459	0.268	3.24	7.15	10.25	14.86	9.70	14.08	296	73	0	0	0	40	2.76	25.9	38.4	3.02
460	.269	3.27	7.20	10.25	14.87	9.71	14.08	296	73	0	0	0	40	2.79	25.8	39.2	3.02
461	.270	3.26	7.18	10.18	14.77	9.65	13.99	295	72	0.77	2.27	3.04	60	2.39	40.1	50.4	2.48
462	.271	3.26	7.20	10.18	14.77	9.65	14.00		72	.78	2.27	3.06	60	2.38	39.6	50.6	2.48
463	.270	3.25	7.15	10.16	14.73	9.65	13.99		71	1.48	3.29	4.76	40	2.24	38.8	48.19	2.57
464	.271	3.26	7.19		14.74	9.64	13.99			1.48	3.32	4.80		2.23	40.1	49.0	2.56
465	.274	3.29	7.26		14.74	9.64	13.98			1.87	3.90	5.77		2.21	41.3	49.5	2.59
466	.273	3.28	7.23		14.74	9.63	13.97			1.86	3.93	5.80		2.20	42.4	49.8	2.55
467	.273	3.28	7.24		14.73	9.64	13.99			1.95	4.07	6.02	60	1.87	42.6	51.6	2.47
468	.273	3.28	7.22	10.17	14.74	9.63	13.97			1.99	4.01	6.00	60	2.05	45.2	52.5	2.41
471	.271	3.26	7.18	10.15	14.73	9.64	13.98			2.14	4.41	6.54	40	2.05	44.0	49.8	2.52
472	.270	3.25	7.16	10.15	14.72	9.65	13.99			2.14	4.35	6.50	40	2.05	43.3	50.6	2.47
475	.271	3.27	7.21	10.22	14.83	9.68	14.04		72	2.05	0	2.05	30	2.65	36.2	47.0	2.65
476	.270	3.27	7.20	10.23	14.83	9.68	14.04		72	2.06	0	2.06	30	2.69	36.4	46.17	2.68
477	.270	3.25	7.16	10.20	14.78	9.67	14.03	296	73	0	0	0	40	2.79	22.6	37.4	3.10
479	.269	3.22	7.11	10.15	14.72	9.62	13.95				1.66	1.66	60	2.71	35.5	46.4	2.64
480	.269	3.23	7.12	10.16	14.73	9.62	13.96				1.74	1.74	60	2.70	35.1	46.3	2.66
482	.270	3.24	7.14	10.14	14.71	9.62	13.95				2.51	2.51	60	2.64	39.0	49.5	2.52
483	.271	3.25	7.17	10.14	14.71	9.61	13.94				3.08	3.08	70	2.59	41.7	50.5	2.50
484	.267	3.20	7.06	10.14	14.70	9.62	13.95				3.14	3.14		2.61	41.5	50.4	2.42
473	.273	3.29	7.26	10.19	14.79	9.65	13.99	295	72		3.89	3.89		2.51	44.4	51.9	2.45
474	.274	3.31	7.29	10.21	14.79	9.65	13.99	295	72		3.91	3.91	70	2.53	44.5	51.7	2.48
485	.269	3.22	7.10	10.14	14.70	9.61	13.94	296	73		4.0	4.0	70	2.53	45.5	52.5	2.35

TABLE I. - Concluded. DIFFUSER PERFORMANCE DATA

Reading	Diffuser inlet Mach number	Airflow rate		Inlet pressure				Inlet total temperature		Inner wall	Outer wall	Total	Exit profile peak		Diffuser effectiveness, η, percent	Diffuser efficiency, ϵ, percent	Total pressure loss, $\Delta P/P$, percent
		kg/sec	lbm/sec	Total		Static				Suction rate, percent			Position, percent of annular span	Ratio, v/V			
				N/cm^2	psia	N/cm^2	psia	K	$^{\circ}$F								
486	0.269	3.23	7.11	10.14	14.70	9.61	13.94	296	73	0	4.1	4.1	70	2.55	45.7	52.3	2.36
487	.268	3.21	7.07	10.12	14.68	9.59	13.91		72	1.47	4.14	5.61	70	2.21	45.6	52.3	2.34
488	.269	3.22	7.10	10.12	14.67	9.59	13.91		73	1.47	4.11	5.59	70	2.25	45.5	52.3	2.36
489	.270	3.22	7.10	10.10	14.65	9.60	13.92			2.47	4.55	7.01	30	2.41	43.2	48.8	2.55
490	.271	3.23	7.13			9.60	13.93			2.47	4.56	7.02		2.38	42.7	49.5	2.53
491	.269	3.21	7.08			9.60	13.92			4.06	4.73	8.80		2.36	42.9	47.9	2.57
492	.270	3.22	7.11			9.59	13.91			4.04	4.64	8.68		2.37	43.8	48.0	2.59
497	.192	2.30	5.08	9.95	14.43	9.69	14.05			0	0	0	40	2.85	27.0	41.8	1.48
498	.190	2.29	5.04	9.95	14.43	9.69	14.05				0	0	40	2.80	26.2	39.7	1.51
499	.191		5.05	9.93	14.39	9.66	14.02				2.56	2.56	60	2.59	40.8	50.3	1.26
500	.191		5.05	9.92			14.01				2.66	2.66	60	2.57	40.9	50.9	1.24
501	.196		5.05				14.01				3.87	3.87	70	2.53	45.3	52.6	1.20
502	.191		5.04				14.01				4.88	4.88		2.47	48.3	53.8	1.17
503	.191		5.05		14.38		14.01				5.59	5.59		2.33	50.1	55.0	1.14
504	.191		5.04	9.91	14.38		14.01				5.60	5.60		2.33	50.0	55.9	1.12
505	.192		5.05	9.92	14.38	9.65	14.00				6.08	6.08		2.22	50.0	54.7	1.15
506	.192		5.06	9.91	14.38	9.66	14.00				6.06	6.06		2.23	50.3	55.9	1.12
495	.192		5.06	9.89	14.35	9.66	14.01			3.67	6.49	10.16	30,60	(a)	49.2	54.2	1.17
496	.193	2.30	5.08			9.64	13.99		72	3.66	6.50	10.16			51.6	54.7	1.17
507	.192	2.29	5.05			9.65	14.00		73	3.68	6.41	10.10			51.0	54.5	1.16
508	.192	2.30	5.07			9.64	13.98		73	3.69	6.56	10.25			52.6	54.6	1.16
509	.191	2.29	5.04	9.90	14.36	9.65	14.00	297	74	2.10	4.40	6.50	40,60		46.4	51.5	1.24
510	.192	2.29	5.04	9.90	14.35	9.64	13.99	297	74	2.10	4.40	6.54	30,60		47.2	52.4	1.21

[a]Unstable profiles.

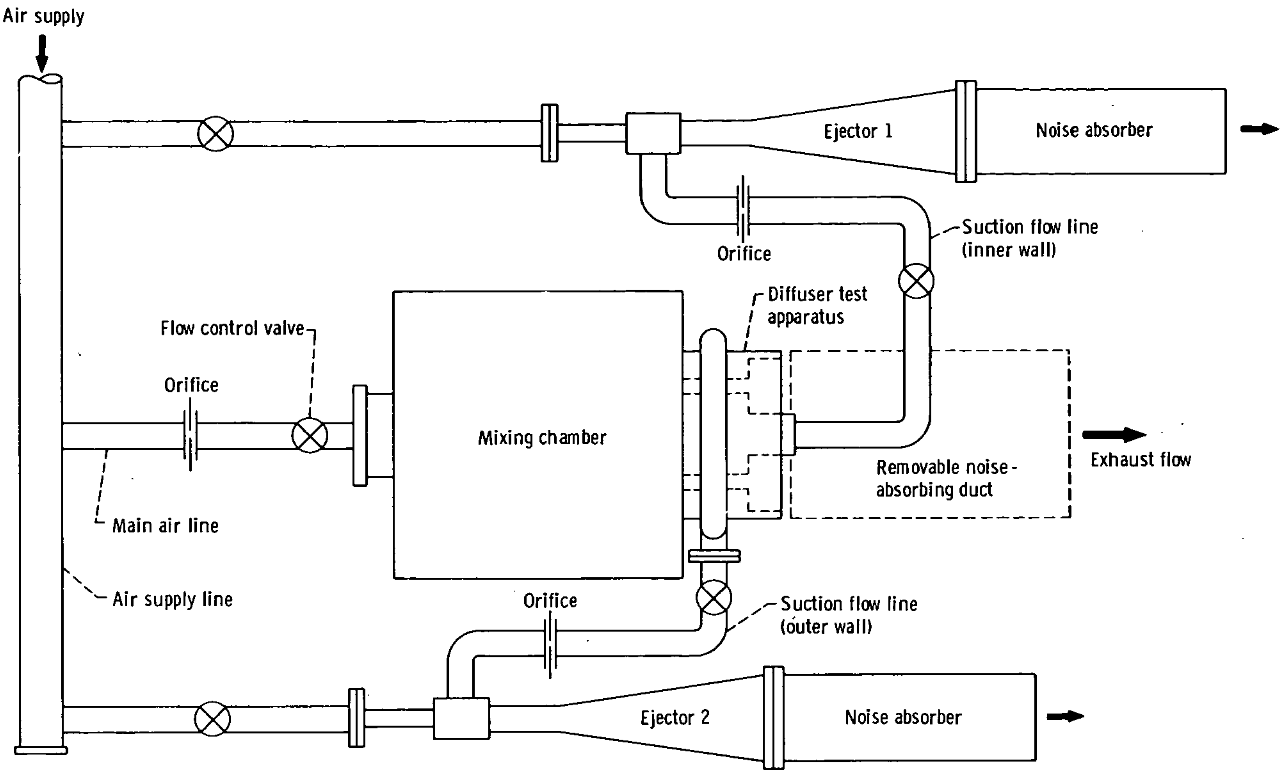


Figure 1. - Flow system.

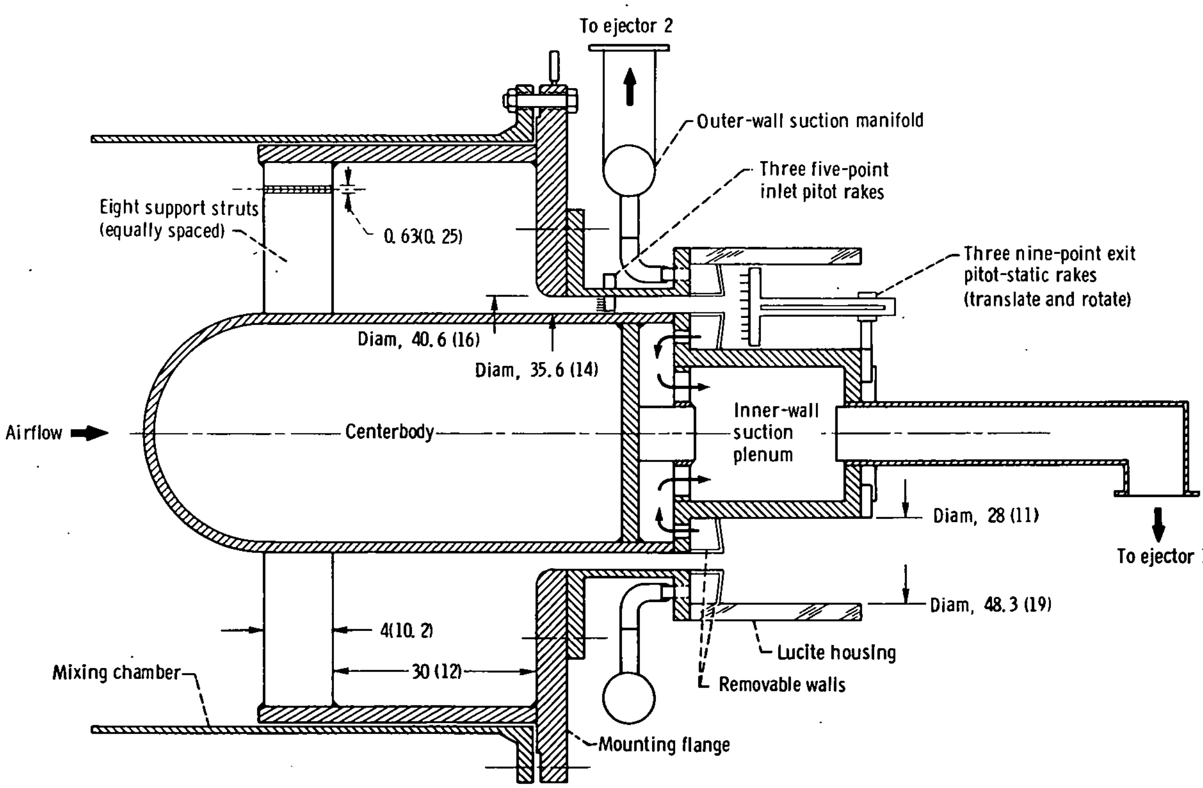


Figure 2. - Cross section of asymmetric annular diffuser test apparatus. (Dimensions are in cm (in.).)

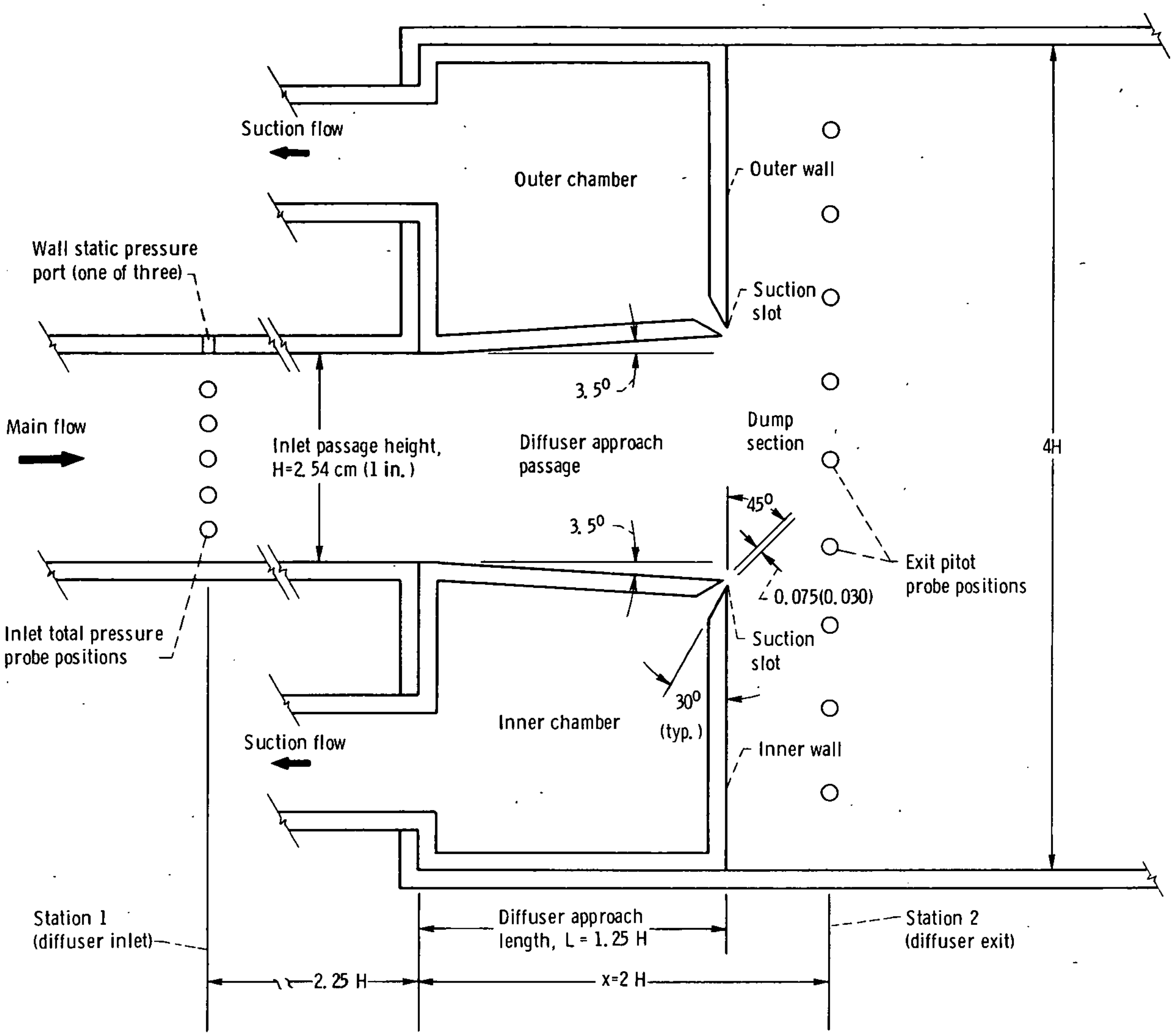


Figure 3. - Details of diffuser wall geometry.

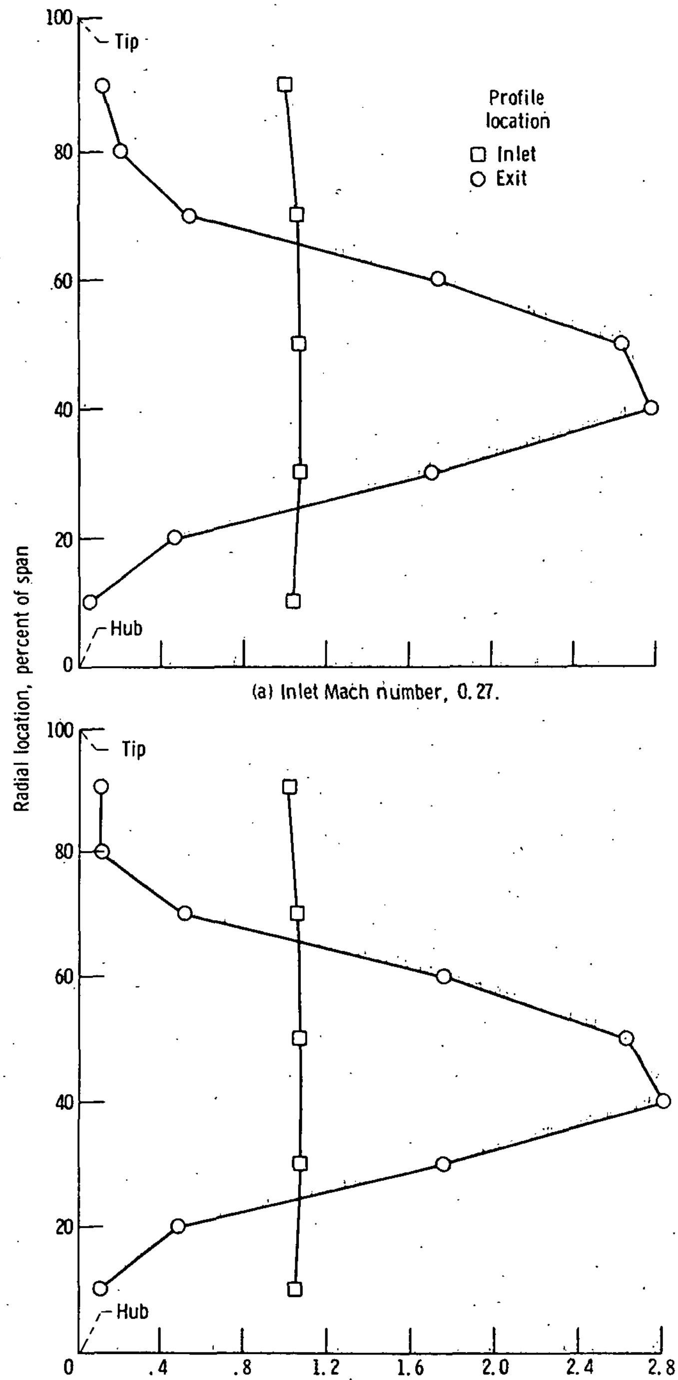
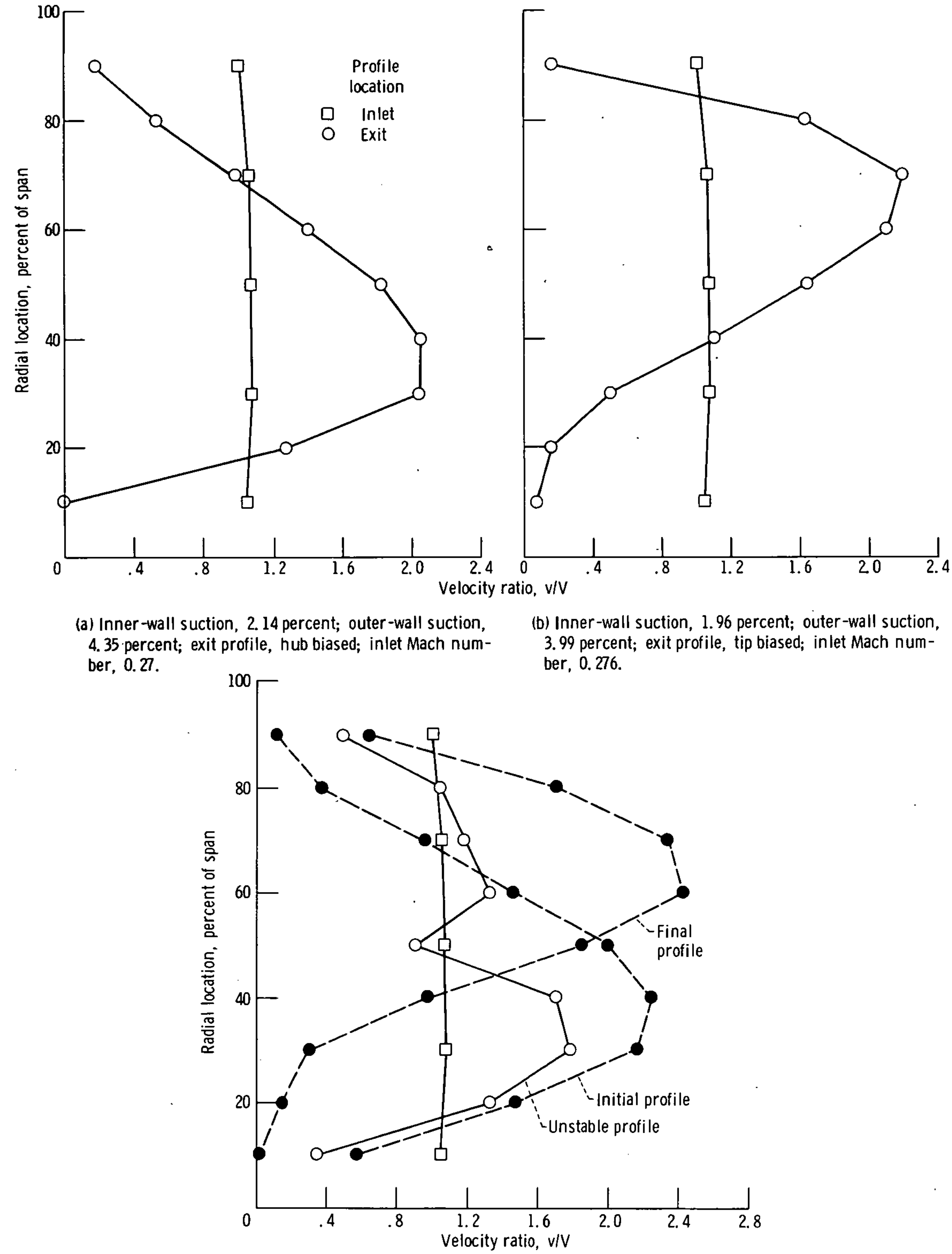


Figure 4. - Radial profiles of diffuser inlet and exit velocity without suction.

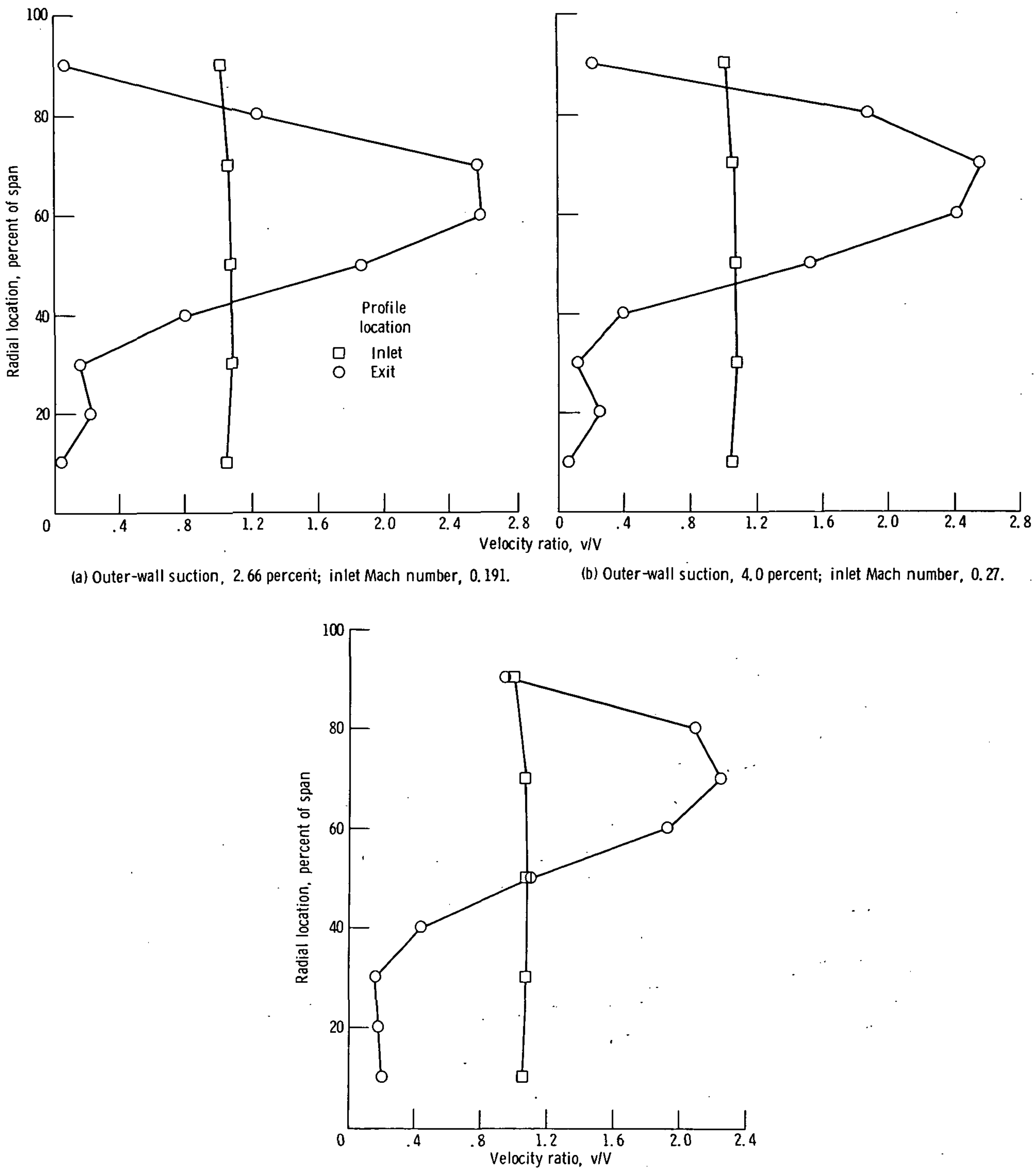


(a) Inner-wall suction, 2.14 percent; outer-wall suction, 4.35 percent; exit profile, hub biased; inlet Mach number, 0.27.

(b) Inner-wall suction, 1.96 percent; outer-wall suction, 3.99 percent; exit profile, tip biased; inlet Mach number, 0.276.

(c) Inner-wall suction, 3.66 percent; outer-wall suction, 6.50 percent; exit profile, unstable; inlet Mach number, 0.193.

Figure 5. - Velocity profiles with suction on both inner and outer walls.



(a) Outer-wall suction, 2.66 percent; inlet Mach number, 0.191.

(b) Outer-wall suction, 4.0 percent; inlet Mach number, 0.27.

(c) Outer-wall suction, 6.06 percent; inlet Mach number, 0.192.

Figure 6. - Velocity profiles with suction on outer wall only.

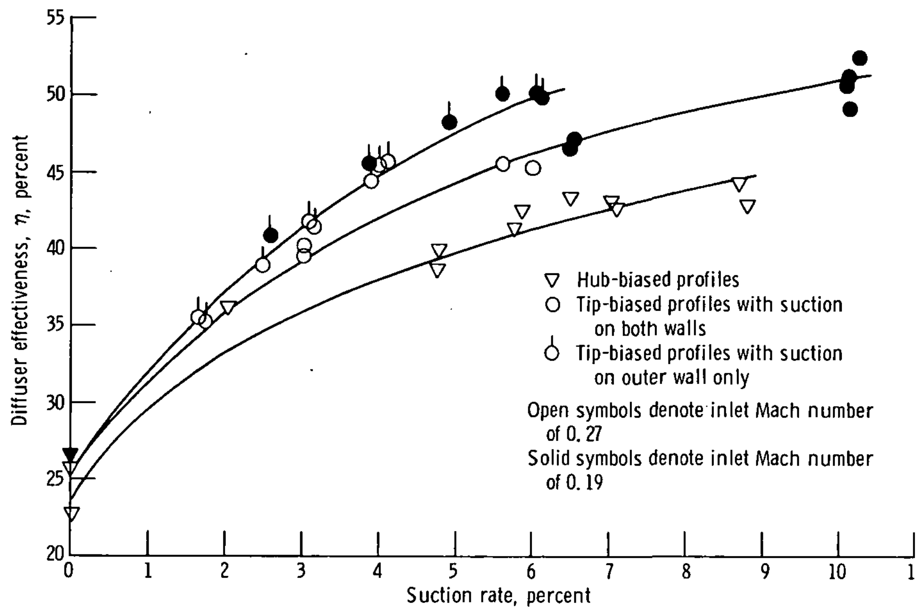


Figure 7. - Effect of suction on diffuser effectiveness.

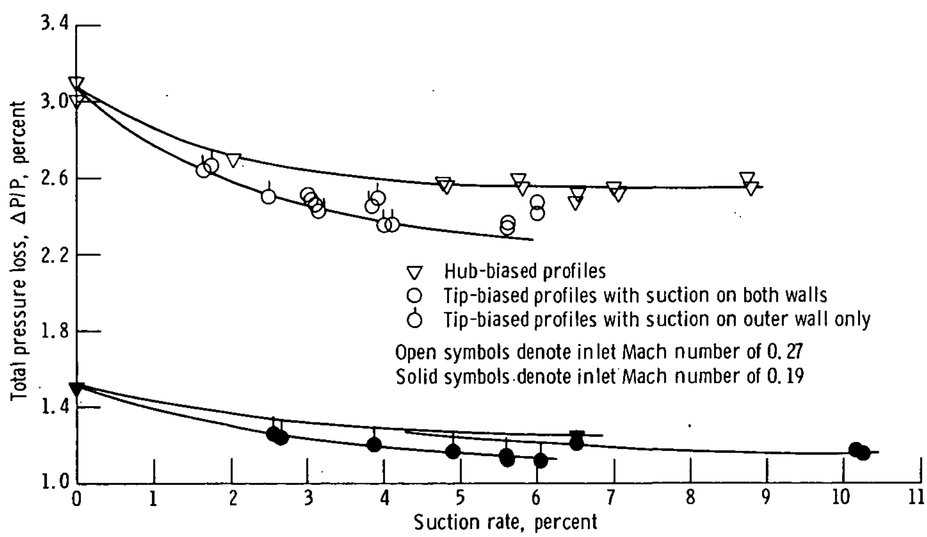


Figure 8. - Effect of suction on diffuser total pressure loss.

NASA-Langley, 1974 E-7944

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546